MINIMIZATION OF SOIL AND NUTRIENT LOSSES IN MAIZE-BASED CROPPING SYSTEMS IN THE MID-HILLS OF CENTRAL NEPAL

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ABSTRACT

Soil nutrient depletion is a major concern in terms of resource utilization and optimization of production in the middle hills of Nepal. Soil and nutrient losses from agricultural land is responsible for pollution of surface waters and this reduces the productive capacity of land. A field experiment was initiated in May 2001 on acidic sandy loam soil in Kavre district; Nepal to investigate the efficiency of widely recommended researchable options for soil conservation. The experimental plots were set up as a two factorial design with three main factors (mulching, reduced tillage and conventional farmers' practice as control) and were divided on the basis of cropping patterns (maize sole and maize inter-cropped with soybean). Soil N, P, K, and OM losses were determined from soil eroded in runoff. Nutrient loss in pre-monsoon period (in the month of May) was highly significant among the management practices. Much of nutrient (60 to 90 percent of annual) losses occurred during this period. As compared to conventional farmers' practice, mulching reduced annual soil organic matter loss by 52 percent, annual total nitrogen by 46 percent, annual available P_2O_5 by 32 percent and annual exchangeable K_2O by 53 percent in maize – mustard cropping system. Similarly, in maize + soybean - mustard cropping system, the annual loss of these nutrients were reduced by 58, 49, 26 and 60 percent, respectively. Reduced tillage, on the other hand, produced higher soil loss and hence more nutrient and organic matter loss as compared to mulching practice because of freshly prepared plots and hence less vegetation and more compaction.

INTRODUCTION

Soil erosion by water may have both positive and negative effects depending on the type, magnitude, and extent of erosion. Geologic erosion is responsible for the formation of the most fertile alluvial soils (Indus valley, Indo-Gangetic plains, Nile delta) that have supported intensive agriculture for millennia for many ancient civilizations (Lal, 1998). However, sheet erosion is a serious problem because of its adverse impacts on agronomic productivity, the environment and ecosystem balances. Sheet erosion, in fact, usually occurs at such a slow rate that its cumulative effects may take decades to become apparent. Miller (1992) has illustrated the nature of this form of soil erosion: ‘removal of one millimeter of soil, an amount easily lost during a rain, is so small that it goes undetected; but the accumulated soil loss at this rate over a 25 years period would amount to 25 mm - an amount that would take about 500 years to replace by natural processes’. As a result of soil loss, plant nutrients are removed; texture is changed; structure deteriorates; production capacity is reduced; fields are dissected and the sediments produced pollute streams and lakes and pile up on bottomlands, in stream channels and in reservoirs (Troeh et al. 1980). Transport and deposition of eroded material as well as substances dissolved in runoff and attached to soil particles lead to negative impacts on agricultural land and adjacent water bodies (Klik, 2000), water quality decline (Wood, et al. 2000; Richards, 2002), eutrophication (Gruhn et al. 2000; Zemenchik, 2002). Soil erosion in the highlands has induced sediment deposition in the terai plains, increasing the potential threat of river course shifts causing damage and property loss over large areas of fertile land. For example, Koshi River has shifted its course to about 110 km from east to west in 232 years (1731 to 1963) destroying about 1300 sq km of fertile land by sand deposition (Ghimire and Upreti, 1997). This sudden change in the position of the river has resulted in a number of ecological changes in the area: forest and grassland in the eastern part of the Koshi tappu reserve have been destroyed, new vegetation has regenerated in the western part, agricultural land became more swampy, and 100-250 meter wide strip of marshes developed in the eastern part (Shah and Suselo, 1996). Upreti and Dhital (1996) documented the reduction of life span of the Kulekhani reservoir by half of the targeted design and one quarter of the expected life span due to sedimentation.

Soil fertility decline due to soil erosion and nutrients losses through runoff and leaching is a serious problem in the hills of Nepal (Tripathi et al. 1999 and 2000; Gardner et al. 2000; Paudyal et al. 2001). The annual loss of soil from agricultural plots ranges from a mere 0.1 t/ha to as high as 105 t/ha (Chalise and Khanal, 1997). Carson in 1992 calculated a nutrient loss of 300-kg organic matter; 15-kg nitrogen, 20-kg phosphorus, and 40-kg potassium by assuming soil loss of 20 t/ha from a marginalized rain fed agricultural land in the mid-hills. A loss of 1-mm topsoil has been estimated to cause loss of 10-kg nitrogen, 7-kg phosphorus and 15 kg of potassium per hectare (Carson, 1992). It was estimated that 1.8 million tones of plant nutrient are removed from soil by crop harvest and soil erosion, and only 0.3 million tones (16 percent) are replenished by organic and inorganic fertilizers (MOPE, 2001). Additionally, in mid-hills, rice-growing farmers are benefited from the accumulation of eroded sediments (Shah, 1996; Schreier and Shah, 2000).

For rain fed agriculture in Nepal, soil erosion is most critical during the pre-monsoon season (Schreier and Shah, 1995; ICIMOD, 1998; Nakarmi and Shah, 2000; Nakarmi et al. 2000; Tripathi, et al. 2000; UNEP, 2001) when vegetation cover is at a minimum, the field is freshly plowed and rainfall intensity is high. In the Central hills of Nepal, approximately 13 percent of rainfall occurs during March-May (pre-monsoon) and 79 percent of rainfall occurs during monsoon period (June-September) and the mid-hills experienced local ascending winds that lead to violent thunderstorms accompanied by hail before the arrival of actual monsoon front (Shah and Friend, 1992).

Strip-cropping (Acharya, 1999; Bajracharya, 2001); minimum tillage (Maskey et al. 1992; Acharya, 1999; Rajbhandari, 2000, Bajracharya, 2001); mulching (Acharya, 1999; Rajbhandari, 2000) and incorporation of legumes (Acharya, 1999) could be the possible options for the soil surface erosion control.

OBJECTIVES

Many field experiments have been conducted to measure soil and nutrient losses through erosion from different land uses such as forest land, degraded land and agricultural land, but only a few of them were targeted to evaluate minimum tillage and none of them to evaluate mulching practices. Thus this research has been initiated with the following objectives:

1. To assess the effect of mulching and reduced tillage on soil loss in maize – mustard and maize + soybean – mustard cropping system.
2. To assess the efficiency of these soil conservation practices in minimizing soil nutrient loss through runoff in the same cropping systems.

It was hypothesized that it is possible to control soil and nutrient losses by practicing mulching and reduced tillage.

MATERIALS AND METHODS

The experimental plots were set up as a 2-factor, split-plot design during summer season of 2001 with six treatment combinations (Table 1) and replicated twice inside the Kathmandu University premises.

Chemical analyses of eroded sediment were done to determine losses of primary nutrients (nitrogen, phosphorus and potassium) and soil organic matter using standard methods at Soil Science Division of NARC. Nitrogen, in the mineralized form of nitrates, is generally believed to be the most important potential limiting factor to plant development in Nepal (NARC, 2000). Potassium is generally believed to be in abundant supply and not a limiting nutrient to crop growth, however, due to its nature of high solubility, few researchers (Shah, 1996; Tripathi, 1999; Gardner et. al. 2000) found the decreasing amount of potassium in soils. Brown and Scheier (2000) established nutrient budget for rain fed agriculture and concluded significant deficits in nitrogen and phosphorus, especially in maize cropping systems

RESULTS AND DISCUSSION

Management effects on runoff and soil loss:

Management practices had no significant effect on total annual runoff. However, conservation practices were effective in controlling soil loss as compared to farmers' practice. Mulching reduced soil loss by about 57 and 53 percent in maize sole and maize inter-cropped with soybean as compared to farmers' practice, respectively. Similarly, these figures for reduced tillage were 13 and 19 percent, respectively (Figure 1). Freshly established plots and hence less vegetation and more compactions caused higher soil loss from reduced till plots as compared to mulching. Further assessment is needed to identify the best practice for soil and water conservation.

Much of the soil loss (52 to 80 percent) occurred during the month of May (Figure 2). Out of the annual soil loss, May accounted for 73 (maize sole) and 80 (maize inter-cropped with soybean) percent soil loss in farmers' practice. Similarly, mulching and reduced tillage yielded 52 (maize sole) and 56 (maize inter-cropped with soybean), and 61(maize sole) and 66 (maize inter-cropped with soybean) percent of the total annual soil loss during the same month, respectively. Thus, mulching and reduced tillage decreased soil erosion by 60 and 63, and 27 and 33 percent as compared to farmers' practice, respectively, in the month of May. The highest soil loss in the month of May was due to freshly plowed field, minimum vegetation cover and high intensity rainfall during the period.

Management effects on soil organic matter loss:
Management practices were significantly different in soil organic matter (SOM) loss by water erosion. The highest loss of SOM from a unit area occurred in farmers' practice followed by reduced tillage. A mulching rate of 5t/ha significantly reduced the SOM loss (by half) as compared to farmers practice (Figure 3). Soil organic matter loss was correlated to total soil loss ($r = 0.80$) rather than amount of runoff ($r = 0.29$). This indicates that much of the SOM loss from farm fields is associated with the eroded sediments i.e. e., particulate organic matter. Thus, higher the soil loss higher will be the SOM loss. The greatest soil loss in farmers practice resulted in highest SOM loss. Similarly, mulching produced lowest SOM loss.

Substantial seasonal variation in SOM loss due to erosion by water was observed. Of the total organic matter loss (May to October), greatest variation occurred in the month of May. In this month, farmer's practice yielded 244.92 kg/ha (maize sole) and 225.22 kg/ha (maize inter-cropped with soybean) where as mulching only produced 90.23 kg/ha (maize sole) and 94.85 kg/ha (maize inter-cropped with soybean), a reduction of 63 and 58 percent in maize sole and maize inter-cropped with soybean respectively. High variations in soil loss among management practices in May resulted in the concurrent variation of SOM loss because these two parameters are directly correlated with each other ($r = 0.86$).

Management effects on soil nutrient loss (N, P & K):
Annual nutrient (N, P & K) losses were significantly different among the management practices. The highest nutrient loss was observed in farmers' practice, which was followed by reduced tillage. The lowest nutrient losses were observed in mulching @ 5t/ha (Figures 4, 5 and 6). The total annual loss of N, P and K in the eroded soil was dependent on total amount of soil loss ($r = 0.93$ for N, 0.7 for P_2O_5 and 0.95 for K_2O). Thus, generally, higher the soil loss higher will be the nutrient loss.

CONCLUSIONS

The aim of this study was to check the hypothesis that practicing mulching and reduced tillage could control soil and nutrients losses in maize – mustard and maize + soybean – mustard cropping patterns on agricultural land of Central Nepal hills. Thus, after one year of micro-level experimentation, the following conclusions were drawn:

1. Rice straw as a mulch material was most effective in controlling soil erosion followed by reduced tillage and thus, could be viable options for mitigating soil erosion problem during pre-monsoon in upland agricultural land of Central Nepal mid-hills.
2. Maintaining any form of plant cover reduces nutrient losses in the eroded soil materials, therefore, in this regard, the beneficial effects of reduced tillage and mulching, with less nutrient losses, were particularly significant.

3. High seasonal variation in soil and nutrient losses was confirmed. Much of the soil (52 to 80 percent) and nutrient (54 to 91 percent) losses occurred during the month of May. Thus, future thrust on soil erosion control should be given to this critical period.
4. Soil organic matter loss as particulate organic matter associated with eroded sediment was quite high from conventional farmers' practice and this may be one of the major causes of fertility depletion of agricultural land in mid-hills of Nepal.
5. Further, on-farm assessment of the influence of management practices on soil and nutrient loss and soil health and productivity is needed.

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Table 1 Treatment combinations of the study

Factor A	Factor B		
Cropping Patterns	Control	Management practices	
	Farmers' Practice C	Mulching @ 5 t/ha M	Reduced Tillage R_t
Maize - Mustard (P_1)	P_1C	P_1M	P_1R_t
Maize plus soybean – Mustard (P_2)	P_2C	P_2M	P_2R_t

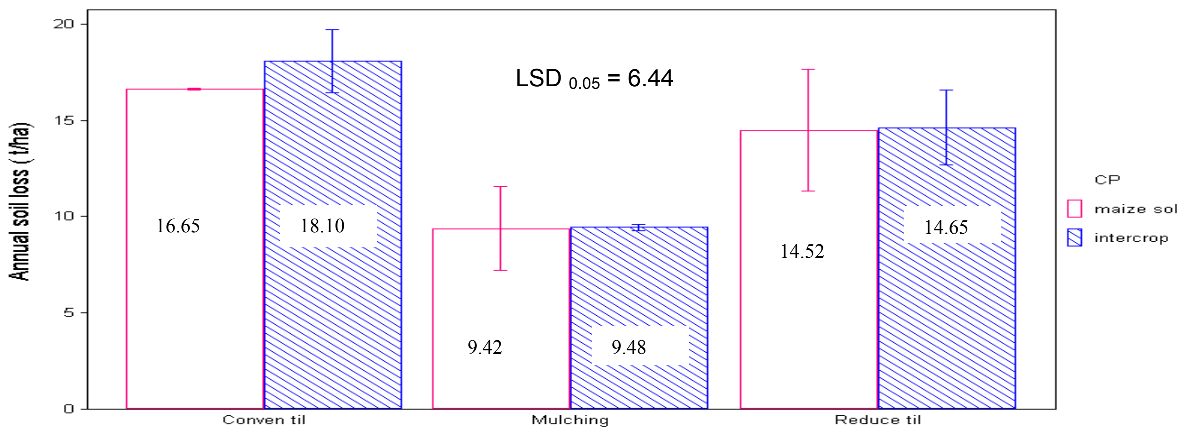

Figure 1 Management effects on annual soil loss

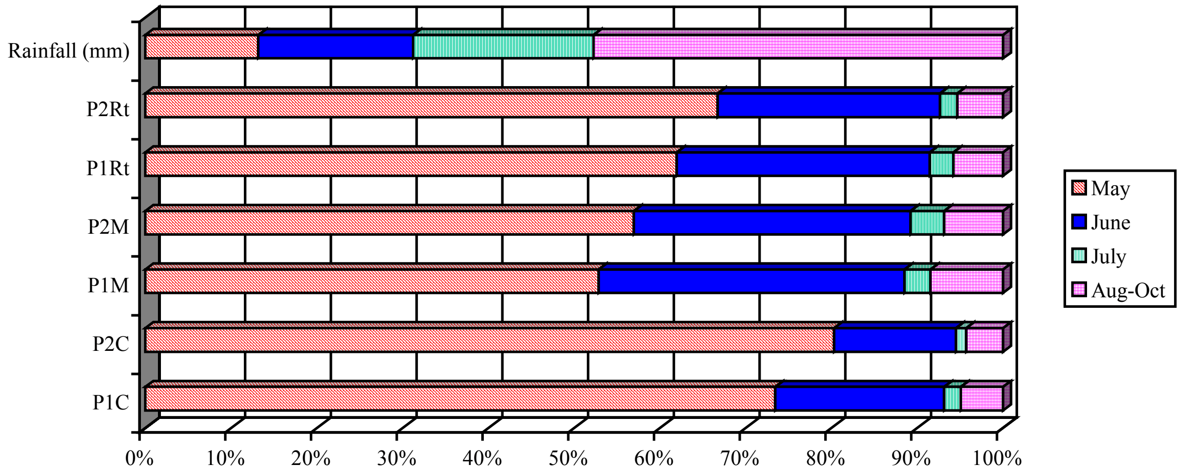

Figure 2 Seasonal variations in soil loss

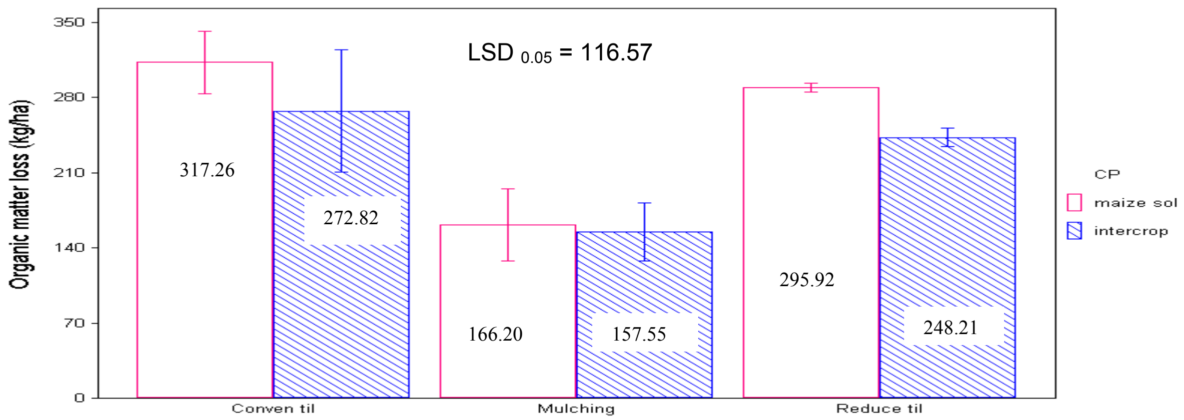

Figure 3 Management effects on soil organic matter loss

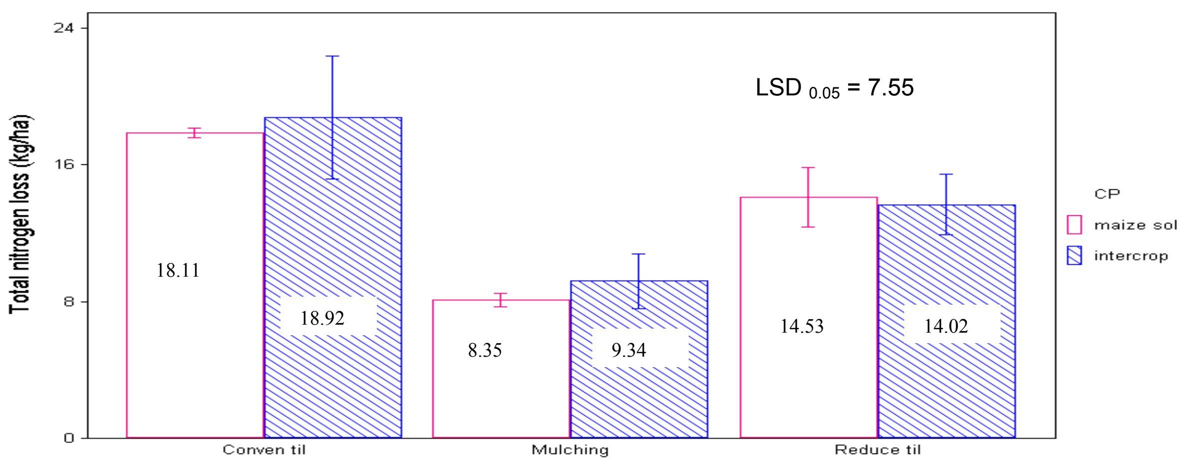

Figure 4 Management effects on total nitrogen loss

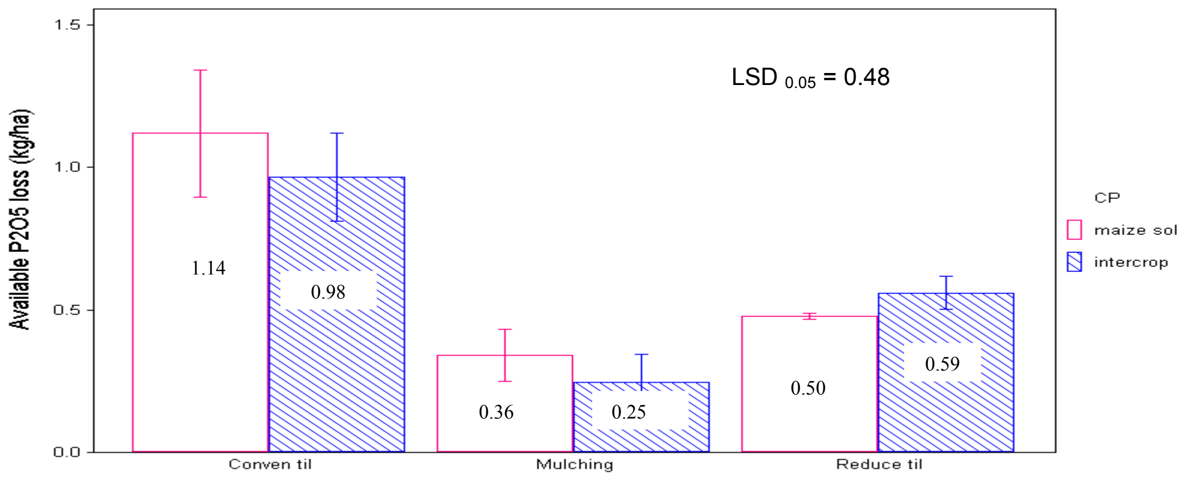

Figure 5 Management effects on plant available P_2O_5 loss

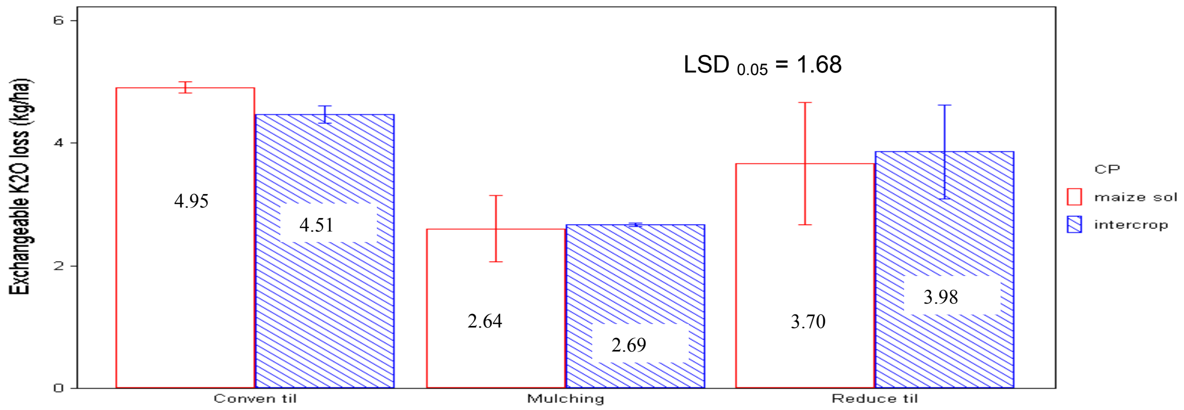

Figure 6 Management effects on exchangeable K_2O loss